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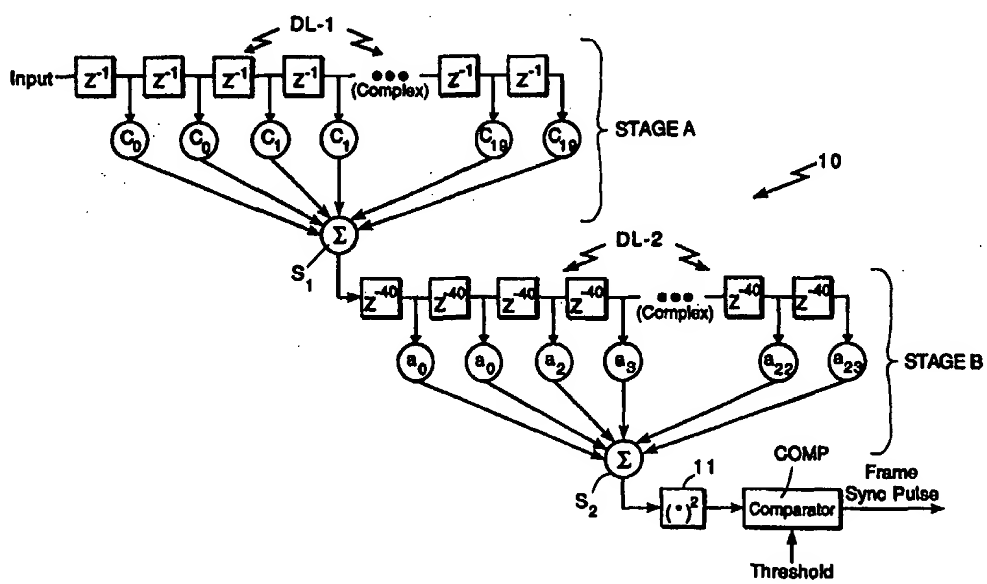

(57) Abstract

A Kronecker product code structure for a synchronization word is presented which permits the use of dual-mode sequential matched filter. This matched filter permits a large reduction in acquisition time since the number of frequency bins that must be searched is greatly reduced when there is a large frequency uncertainty. In the first mode of operation the output of a filter matched to the high rate code is non-coherently integrated in a post-detection integrator to obtain reliable but ambiguous acquisition of the synchronization word. In the second mode of operation the ambiguity is resolved.

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KRONECKER PRODUCT CODE ACQUISITION SYSTEM

Field of the Invention

This application applies to the design of a rapid acquisition synchronization word system for those cases in which there is significant time and frequency uncertainty. The objective is to find a minimal length synchronization word with a relatively simple receiver that offers rapid time and frequency acquisition.

Background of the Invention

It is common practice to periodically insert a fixed synchronization word in a data stream (using time-division multiplexing)so as to assist the various receivers in a system in achieving the timing and frequency necessary to successfully demodulate the received signal. It is desirable to use this fixed code word (ideally having pseudo-random properties leading to an aperiodic autocorrelation function with low sidelobes) since it can speed acquisition as compared to what can be done by directly synchronizing to the data stream which may not have a good autocorrelation function. However, use of this dedicated synchronization word does use a portion of time and communication resources that would otherwise have been available for the data stream. Consequently, it is desirable to minimize the length and the duty factor of this periodic synchronization signal.

On the other hand, in many applications, it is important to acquire this synchronization signal quickly in the face of unknown time and large frequency uncertainty with a relatively simple receiver. A good example of this situation is in satellite-based cellular telephone service.

Most such systems use low- or medium- earth orbit altitude satellites to reduce the transmit power required from the mobile units. The use of such orbits results in substantial frequency uncertainty on the order of several to many tens of kHz. Often, due to the weak link budgets, the data rates for these systems is very low (on the order of 4.8 kb/s) and the signals are heavily coded. As a result the received carrier-power-to-noise-power-spectral-density ratio, or C/No, is very low. Thus, it is necessary to correlate the received signal over a substantial length of time to achieve a sufficiently high energy-per-synchronization-word-to-noise-power-spectral-density-ratio to permit reliable acquisition of the synchronization word. If a single matched-filter detector is used for acquisition it will be necessary to have a very accurate frequency estimate for good performance. The accuracy of the frequency estimate is inversely proportional to the length of the synchronization word. With a single matched filter MF, this means that it would be necessary to try many different frequency bins. In many applications this approach results in unacceptably long acquisition process. Figure 1 illustrates a block diagram of this sequential approach where a voltage-controlled oscillator (VCO) is used to select the frequency bin.

An alternative to a single matched filter is the use of multiple matched filters MF1, MF2...MFN -- each one tuned to one of the many frequency bins. Figure 2 is a block diagram of the parallel approach. Unfortunately, each matched filter is reasonably complex and the requirement for multiple units, e.g., 20 more, results in excessive equipment and power consumption. For the mobile phone example, power consumption is of great concern since the mobile phones are battery operated.

Thus, significant problems exist with the conventional sequential and parallel approaches to the acquisition of the synchronization word. The invention presented herein solves these problems resulting in the minimum length synchronization word yielding the desired reliability of acquisition with a receiver of acceptable complexity and power consumption.

To this point, for tutorial purposes, the background material has selected the example of time division multiplexing for the insertion of the synchronization word in a data stream. There are other applications, e.g., ranging systems, in which there is no data to be transmitted, and, also, there are alternative methods (to time division multiplexing) for combining the data and the synchronization signal. Those skilled in the art will easily recognize that the innovative concepts for rapid acquisition presented herein are directly applicable to such problems.

Summary of the Invention

The fundamental concept is the use of a 2-level Kronecker product (Bellman, Richard, Introduction to Matrix Analysis, McGraw-Hill, 1960, New York) code with a dual-mode matched filter. A Kronecker product code consists of a binary high rate code which is periodically repeated (for the length of the low rate code) with or without sign inversion as defined by the low rate code. Thus, the length of the Kronecker product code is the product of the lengths of the two codes. This product code has a lot of structure in the sense that the high rate code is repeated but with possible sign inversion. In order to achieve the best overall aperiodic autocorrelation properties of the product code it is desirable that both

the low- and high- rate codes have good aperiodic autocorrelation properties. As a representative example, one could use Neuman-Hofman codes(Neuman, F., and Hofman, L., "New Pulse Sequences with Desirable Correlation Properties," *Proc. National Telemetry Conference*, 1971, pp. 272-282) of length 20 and 24 to produce a code of length 480. Figure 3 illustrates the Kronecker product code for this example. There are many other possibilities some of which might produce a better aperiodic autocorrelation function. Neuman-Hofman (NH) codes have been selected as the example since it is known they are the best possible codes of a given length in that they minimize the size of the peak sidelobe of the autocorrelation function. Because of this fact a NH code is the best choice for the high rate code and a very reasonable candidate for the low rate code.

An objective of the invention is to reduce the number of required trial frequencies by exploiting the Kronecker product nature of the synchronization signal.

The invention features a communication system for communicating between a plurality of stations wherein, at the RF transmitters, a synchronization word signal is periodically inserted in a data stream to assist the stations in achieving timing and frequency accuracy to successfully demodulate a received data stream, and to minimize the length and duty factor of the synchronization (sync) word and the time required to acquire synchronization. The synchronization word signal is generated from a Kronecker product code and the RF receivers have detectors detecting Kronecker product code synchronization word and achieving synchronization. In a preferred embodiment the Kronecker product code is a two-level Kronecker product code, and the detector includes a dual stage matched filter, particularly a dual mode

sequential matched filter. In a further preferred embodiment, a sequential matched filter means is arranged to operate in post detection integration mode and reduce frequency sensitivity of the detection process. Further, the detector means includes a sequential matched filter means arranged to operate in post detection integration mode and thereby gain high rate code chip synchronization. In a further aspect of the invention the Kronecker product code is a two-level Kronecker product code and wherein one of said levels is a high rate Neuman-Hofman code.

In a further feature of the invention, the Kronecker product code is a two-level Kronecker product code and wherein one of the levels is a low rate Neuman-Hofman code.

Yet a further feature of the invention, the Kronecker product code is a two-level Kronecker product code, wherein one of the code levels is a high rate Neuman-Hofman code and one of the code levels is a low rate Neuman-Hofman code.

In still a further feature of the invention, the detector means includes a dual stage matched filter means and decimator means coupling the stages.

Description of the Drawings

The above and other objects, advantages and features of the invention will become more apparent when taken with the following specification and accompanying drawings, wherein:

Fig. 1 (prior art) is a block diagram of a conventional receiver and synchronization word detector,

Fig. 2 (prior art) is a block diagram of the parallel approach to matched filter detector,

Fig. 3 is a diagrammatic illustration of a Kronecker product code created from a 20 chip NH high rate code and a 24 chip NH low rate code and incorporated in the invention,

Fig. 4 is a block diagram of optimal matched-filter detector for the synchronization word incorporating the invention,

Fig. 5 is a block diagram of sequential matched-filter detector for sync word (operating in post-detection integration (PDI) mode),

Fig. 6 is a block diagram of a sequential matched-filter detector for synchronization word (operating in fully coherent mode),

Fig. 7 is a block diagram of a representational transmitter illustrating time division multiplexing (TDM) of the synchronization (sync) word signal,

Fig. 8 shows a time division frame structure illustrating the placement of the sync word,

Fig. 9 is a block diagram of a representative receiver,

Fig. 10*a* is an overall system diagram for point-to-point links, and

Fig. 10*b* is an overall system diagram for points-to-multipoint links or a star system.

Detailed Description

Referring now to Fig. 4, there is shown a dual-stage, stage 1 and stage 2 coherent matched filter 10 (for the example used above) where the product nature of the code has been utilized to reduce the number of required taps. The first stage, stage A, of the matched filtering is accomplished by a tapped delay line DL-1 whose coefficients are matched to the high rate code. In this example it is assumed that there are two samples per chip. Thus, each high rate chip is represented by two taps (CO, CO, C1, C1...C19, C19), and the delay associated with each tap is one-half of a high rate chip duration. The second stage, stage B, of matched filtering operates on the output from summer S1 of the first stage of matched filtering. For this stage the tap spacing is one low rate chip in duration and there is only one tap per chip (AO, A1, A2, A3...A23). The sampling rate is not reduced in this second stage and it is necessary to have as many shift register stages as twice the length of the product code. However, the number of taps is greatly reduced with respect to the number that would exist if one were to directly matched filter to the product code in a single stage.

Note that it is necessary to have selected the down converter frequency sufficiently accurately that the carrier phase does not change significantly over the 960 samples representing the Kronecker product code. In other words the required frequency accuracy is inversely proportional to the length of the matched filter. If there is a large frequency uncertainty, then it will be necessary to try many different frequencies either sequentially or in parallel. The objective of the invention is to reduce the number of required trial frequencies by exploiting the Kronecker product nature of the synchronization signal.

The output from summer S2 is passed through detector 11, threshold comparator 12 and outputted as the frame sync pulse for the system.

According to the invention, in a preferred embodiment a dual-mode sequential matched filter based on the concept of the dual-stage matched filter is used. The word "sequential" is used since the matched filter is first operated in one mode and then after acquisition(in this mode) it sequences to the second mode for final acquisition. In the first mode the high rate code is acquired non-coherently but there are many ambiguities due to the repetitive use of this code (or its complement). In the second mode these ambiguities are resolved through the coherent use of the low rate code.

The matched filter is comprised of two major parts which are operated in two different modes. In the first mode of operation which we call the post-detection integration mode the block diagram is given by Fig. 5. In this mode, which is the first stage of operation, the output of the high rate matched filter, stage SHR, is envelope detected, detector D3, and passed along to a moving average filter MAF which is the same length as the low rate code. This moving average filter performs the post-detection integration (PDI) function and increases the output signal-to-noise ratio (SNR) to the point where reliable detection occurs when the received signal is properly aligned in time and frequency in the two stage matched filter. For the representative example cited above in which the high rate code is of length 20 the sensitivity to frequency error is reduced by a factor of 24. Thus, in many cases it will not be necessary to sequentially try different bins and in other cases the number of bins will be greatly reduced.

Assuming more than one frequency bins are tried the bin with the maximum output is selected for processing in the second mode of operation. Since the high rate code or its complement is repeated as many times as the length of the low rate code there are multiple ambiguities in the detection of the synchronization word. These ambiguities are spaced by the length of the high rate code. It is the function of the second mode of operation to resolve these ambiguities.

In the second mode of operation, full coherent matched filter operation is performed. by sequentially trying different frequency bins. These bins are now much more closely spaced since the coherent integration interval is much longer, e.g., 24 times longer for the example cited above. Figure 6 is a block diagram of the sequential matched filter operating in the fully coherent mode. The output of summer $S1^1$ is detected in detector 15, compared with a predetermined threshold in comparator 16 and used to control decimator 17 which outputs the decimated signal to filter stage B^1 whose output is detected 18, and compared with a predetermined threshold in comparator 19 which outputs the frame sync pulse as shown. Note that in this mode of operation it is possible to reduce the sampling rate, by a factor of 40 in the selected example, of the low rate code matched filter. Operation in the earlier PDI mode has derived short code word synchronization, which is equivalent to low rate code chip synchronization since there is one high rate code period per low rate code chip. Thus, low rate code matched filter has only as many taps as there are in its length measured in chips.

Acquisition is declared when the power output of the coherent stage of matched filtering exceeds the selected threshold value.

Referring now to Figures 7 and 8, the invention is shown in context of a time division multiplexed communication system in which a traffic data stream from a data source is compression buffered in buffer 20 and the Kronecker product based synchronization word is generated in synchronization word generator 21. The data traffic and sync word signals are timed by time base generator 22 and multiplexed into frames (Fig. 8) by time division multiplexer 22. The frames of sync words and data traffic are imposed or carried by modulator 24 and upconverted by upconverter 25 and oscillator 26, power amplified 27 and broadcast by antenna 28.

Referring to Fig. 9, RF broadcast signals are received by antenna 29, amplified in low noise amplifier 30 and downconverted by downconverter 31. As shown, downconverter 31 receives as one input the amplified signal from amplifier 30 and a signal from number controlled oscillator or synthesizer 32, which, in turn, receives a frequency control signal from microprocessor 33 which performs the frequency search. These components are essentially conventional. The synchronization described earlier herein is carried out in the sync word detector and synchronizer 34. The detectors shown in Figs. 5 and 6 function in sync word detector 34. The time base is generated by time base generator 35 which is driven by number controlled oscillator 36 which is controlled by from the sync word generator detector, and synchronizer 34. Having achieved synchronization the signals are demultiplexed 37, buffered in expansion buffer 38, demodulated in traffic demodulator 39, and the traffic outputted to a utilization device 40. It is obvious that the invention can be for synchronization in a wide variety of systems such as point-to-point links (Fig. 10*a*) and point-to-multipoint links (Fig. 10*b*).

The invention features the following:

1. Use of a dual stage matched filter with Kronecker product codes to reduce the number of taps in the matched filter.
2. Use of Kronecker product codes with dual-mode sequential matched filter to acquire synchronization signal.
3. Use of PDI mode with Kronecker product codes to reduce frequency sensitivity of the detection process
4. Use of the PDI mode to gain low rate code chip synchronization
5. Use of low rate code chip synchronization to reduce the complexity of the low rate code matched filter through the process of decimation.
6. Use of a Neuman-Hofman code as the high rate code in a dual level Kronecker product code.
7. Use of a Neuman-Hofman code as the low rate code in a dual level Kronecker product code.
8. Use of Neuman-Hofman code for both the high and low rate codes in a dual level Kronecker product code.

While preferred embodiments of the invention have been illustrated and described, it will be apparent to those skilled in the art that other embodiments, modifications and adaptations of the invention are possible.

WHAT IS CLAIMED IS:

1. In an RF communication system for communicating between a plurality of stations wherein a synchronization (sync) word signal is periodically transmitted to assist said stations in achieving timing and frequency accuracy to successfully demodulate a received data stream, the improvement for minimizing the length said sync word and the time required to acquire synchronization, comprising, means for generating said synchronization word signal from a Kronecker product code.

2. In an RF communication system as defined in claim 1 wherein said Kronecker product code is a two-level Kronecker product code.

3. In an RF communication system as defined in claim 2 including means for detecting said two-level Kronecker product code and wherein said means for detecting includes a dual stage matched filter.

4. In an RF communication system as defined in claim 3 wherein said means to detect includes dual mode sequential matched filter means.

5. In an RF communication system as defined in claim 3 wherein said means to detect includes a sequential matched filter means arranged to operate in post detection integration mode and reduce frequency sensitivity of the detection process.

6. In an RF communication system as defined in claim 3 wherein said detector means includes a sequential matched filter means arranged to operate in post detection

integration mode and thereby gain low rate code chip synchronization.

7. In an RF communication system as defined in claim 1 wherein said Kronecker product code is a two-level Kronecker product code and wherein one of said levels is a high rate Neuman-Hofman code.

8. In an RF communication system as defined in claim 7 wherein said Kronecker product code is a two-level Kronecker product code and wherein one of said levels is a low rate Neuman-Hofman code.

9. In an RF communication system as defined in claim 1 wherein said Kronecker product code is a two-level Kronecker product code and wherein one of said code levels is a high rate Neuman-Hofman code and one of said code levels is a low rate Neuman-Hofman code.

10. In an RF communication system as defined in claim 1 wherein said means for detecting includes a dual stage matched filter means and decimator means coupling said stages.

11. In an communication system having a plurality of stations each having RF transmitters and RF receivers communicating in time division multiplex (TDM) mode and wherein at said RF transmitters a synchronization (sync) word signal is periodically inserted in a data stream to assist said stations in achieving timing and frequency accuracy to successfully demodulate a received data stream, the improvement for minimizing the length and duty factor of said sync word and the time required to acquire synchronization, comprising, means at said transmitters for generating said sync word signal from a Kronecker product

code and means at said RF receivers for detecting said sync word and achieving synchronization.

12. In an RF communication system as defined in claim 11 wherein said Kronecker product code is a two-level Kronecker product code.

13. In an RF communication system as defined in claim 12 wherein said means for detecting includes a dual stage matched filter.

14. In an RF communication system as defined in claim 12 wherein said means to detect includes dual mode sequential matched filter means.

15. In an RF communication system as defined in claim 12 wherein said detector means includes a sequential matched filter means arranged to operate in post detection integration mode and reduce frequency sensitivity of the detection process.

16. In an RF communication system as defined in claim 12 wherein said detector means includes a sequential matched filter means arranged to operate in post detection integration mode and thereby gain low rate code chip synchronization.

17. In an RF communication system as defined in claim 11 wherein said Kronecker product code is a two-level Kronecker product code and wherein one of said levels is a high rate Neuman-Hofman code.

18. In an RF communication system as defined in claim 11 wherein said Kronecker product code is a two-level

Kronecker product code and wherein one of said levels is a low rate Neuman-Hofman code.

19. In an RF communication system as defined in claim 11 wherein said Kronecker product code is a two-level Kronecker product code and wherein one of said code levels is a high rate Neuman-Hofman code and one of said code levels is a low rate Neuman-Hofman code.

20. In an RF communication system as defined in claim 11 wherein said means for detecting includes a dual stage matched filter means and decimator means coupling said stages.

AMENDED CLAIMS

[received by the International Bureau on 20 April 1998 (20.04.98); original claims 1-20 replaced by amended claims 1-20 (4 pages)]

1. An RF communication system for communicating between a plurality of stations wherein a synchronization (sync) word signal is periodically transmitted to assist said stations in achieving timing and frequency accuracy to successfully demodulate a received data stream, the improvement for minimizing the length said sync word and the time required to acquire synchronization, characterized by means for generating said synchronization word signal from a Kronecker product code.

2. An RF communication system as defined in claim 1 wherein said Kronecker product code is a two-level Kronecker product code.

3. An RF communication system as defined in claim 2 including means for detecting said two-level Kronecker product code and wherein said means for detecting includes a dual stage matched filter.

4. An RF communication system as defined in claim 3 wherein said means to detect includes dual mode sequential matched filter means.

5. An RF communication system as defined in claim 3 wherein said means to detect includes a sequential matched filter means arranged to operate in post detection integration mode and reduce frequency sensitivity of the detection process.

6. An RF communication system as defined in claim 3 wherein said detector means includes a sequential matched filter means arranged to operate in post detection

integration mode and thereby gain low rate code chip synchronization.

7. An RF communication system as defined in claim 1 wherein said Kronecker product code is a two-level Kronecker product code and wherein one of said levels is a high rate Neuman-Hofman code.

8. An RF communication system as defined in claim 7 wherein said Kronecker product code is a two-level Kronecker product code and wherein one of said levels is a low rate Neuman-Hofman code.

9. An RF communication system as defined in claim 1 wherein said Kronecker product code is a two-level Kronecker product code and wherein one of said code levels is a high rate Neuman-Hofman code and one of said code levels is a low rate Neuman-Hofman code.

10. An RF communication system as defined in claim 1 wherein said means for detecting includes a dual stage matched filter means and decimator means coupling said stages.

11. An communication system having a plurality of stations each having RF transmitters and RF receivers communicating in time division multiplex (TDM) mode and wherein at said RF transmitters a synchronization (sync) word signal is periodically inserted in a data stream to assist said stations in achieving timing and frequency accuracy to successfully demodulate a received data stream, the improvement for minimizing the length and duty factor of said sync word and the time required to acquire synchronization, characterized by means at said transmitters for generating said sync word signal from a

Kronecker product code and means at said RF receivers for detecting said sync word and achieving synchronization.

12. An RF communication system as defined in claim 11 wherein said Kronecker product code is a two-level Kronecker product code.

13. An RF communication system as defined in claim 12 wherein said means for detecting includes a dual stage matched filter.

14. An RF communication system as defined in claim 12 wherein said means to detect includes dual mode sequential matched filter means.

15. An RF communication system as defined in claim 12 wherein said detector means includes a sequential matched filter means arranged to operate in post detection integration mode and reduce frequency sensitivity of the detection process.

16. An RF communication system as defined in claim 12 wherein said detector means includes a sequential matched filter means arranged to operate in post detection integration mode and thereby gain low rate code chip synchronization.

17. An RF communication system as defined in claim 11 wherein said Kronecker product code is a two-level Kronecker product code and wherein one of said levels is a high rate Neuman-Hofman code.

18. An RF communication system as defined in claim 11 wherein said Kronecker product code is a two-level

Kronecker product code and wherein one of said levels is a low rate Neuman-Hofman code.

19. An RF communication system as defined in claim 11 wherein said Kronecker product code is a two-level Kronecker product code and wherein one of said code levels is a high rate Neuman-Hofman code and one of said code levels is a low rate Neuman-Hofman code.

20. An RF communication system as defined in claim 11 wherein said means for detecting includes a dual stage matched filter means and decimator means coupling said stages.

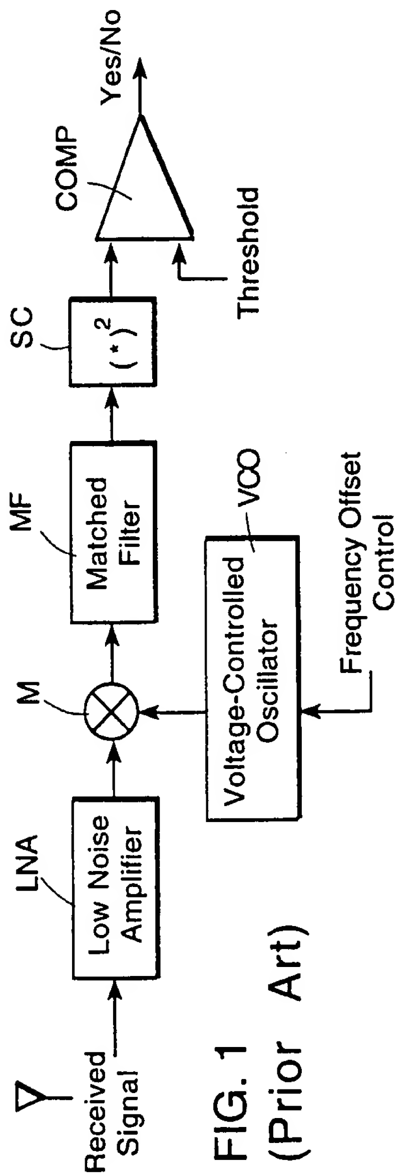


FIG. 1 (Prior Art)

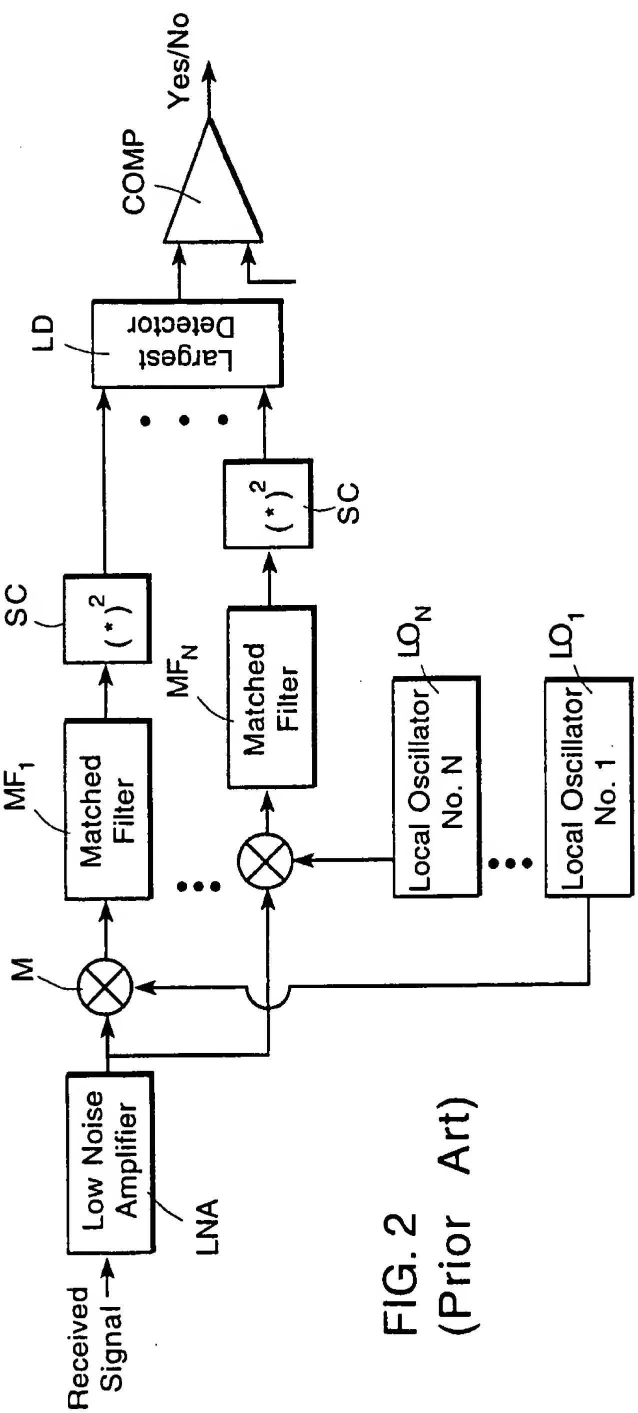
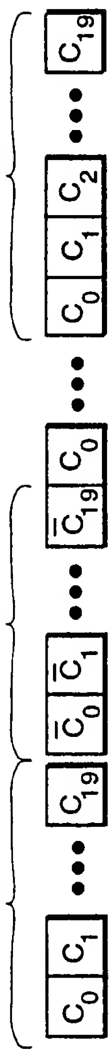


FIG. 2 (Prior Art)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a1
a23
C0
C1
C19
C2

FIG. 3

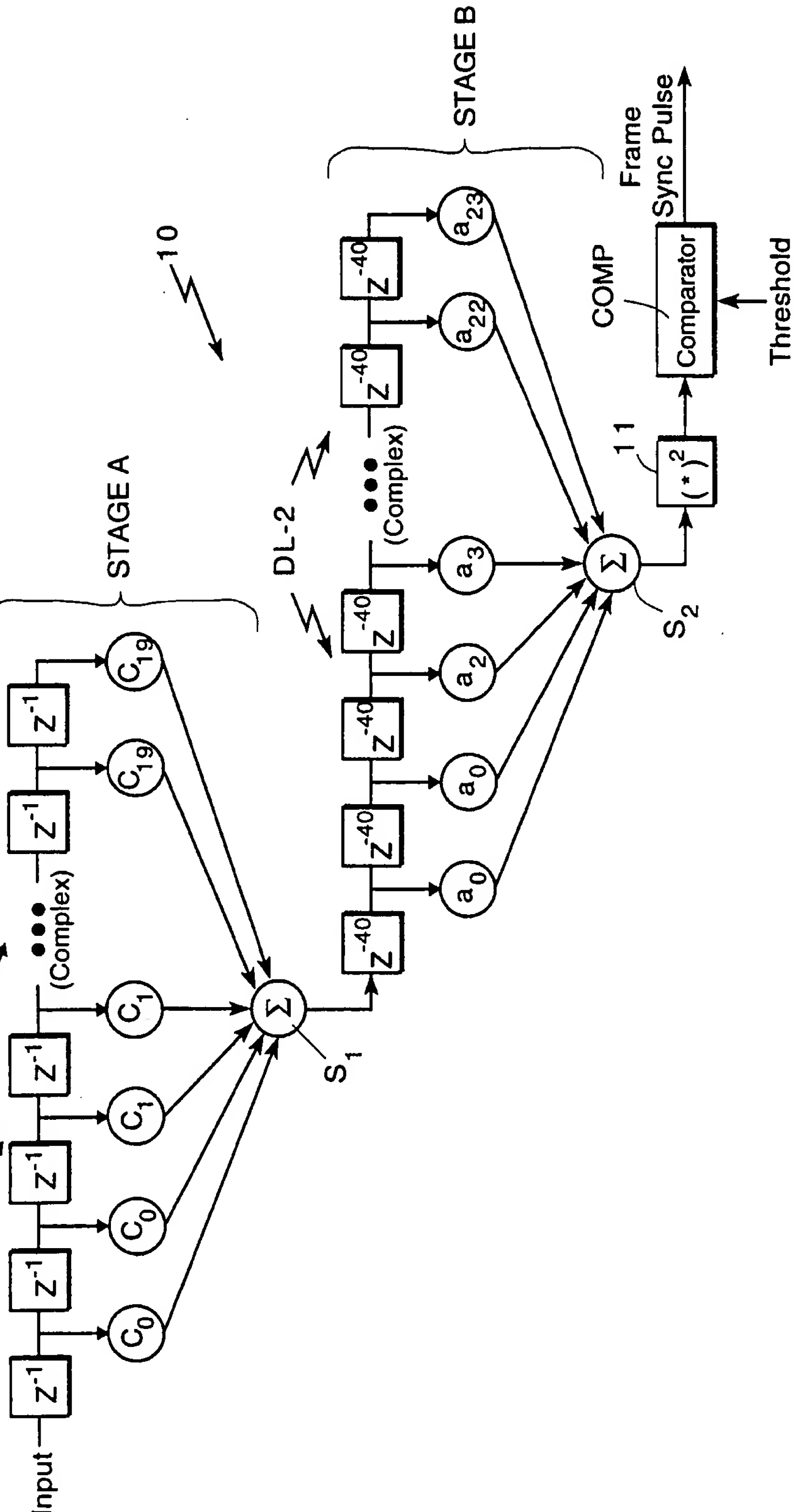
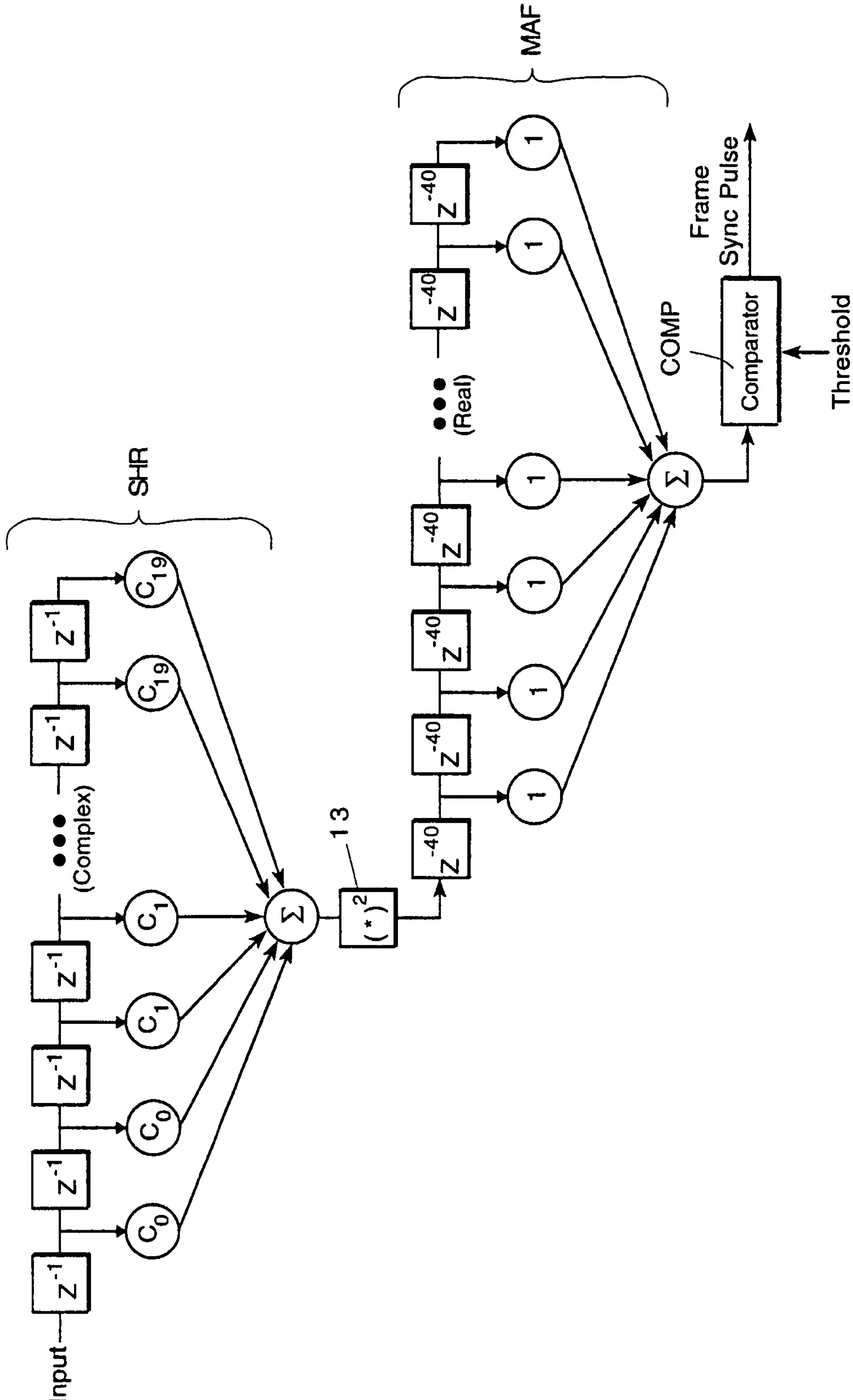

Input
DL-1
(Complex)
STAGE A
S1
DL-2
(Complex)
STAGE B
S2
10
11
COMP
Comparator
Threshold
Frame
Sync Pulse

FIG. 4

FIG. 5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C_1
(Complex)
C_{19}
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Σ
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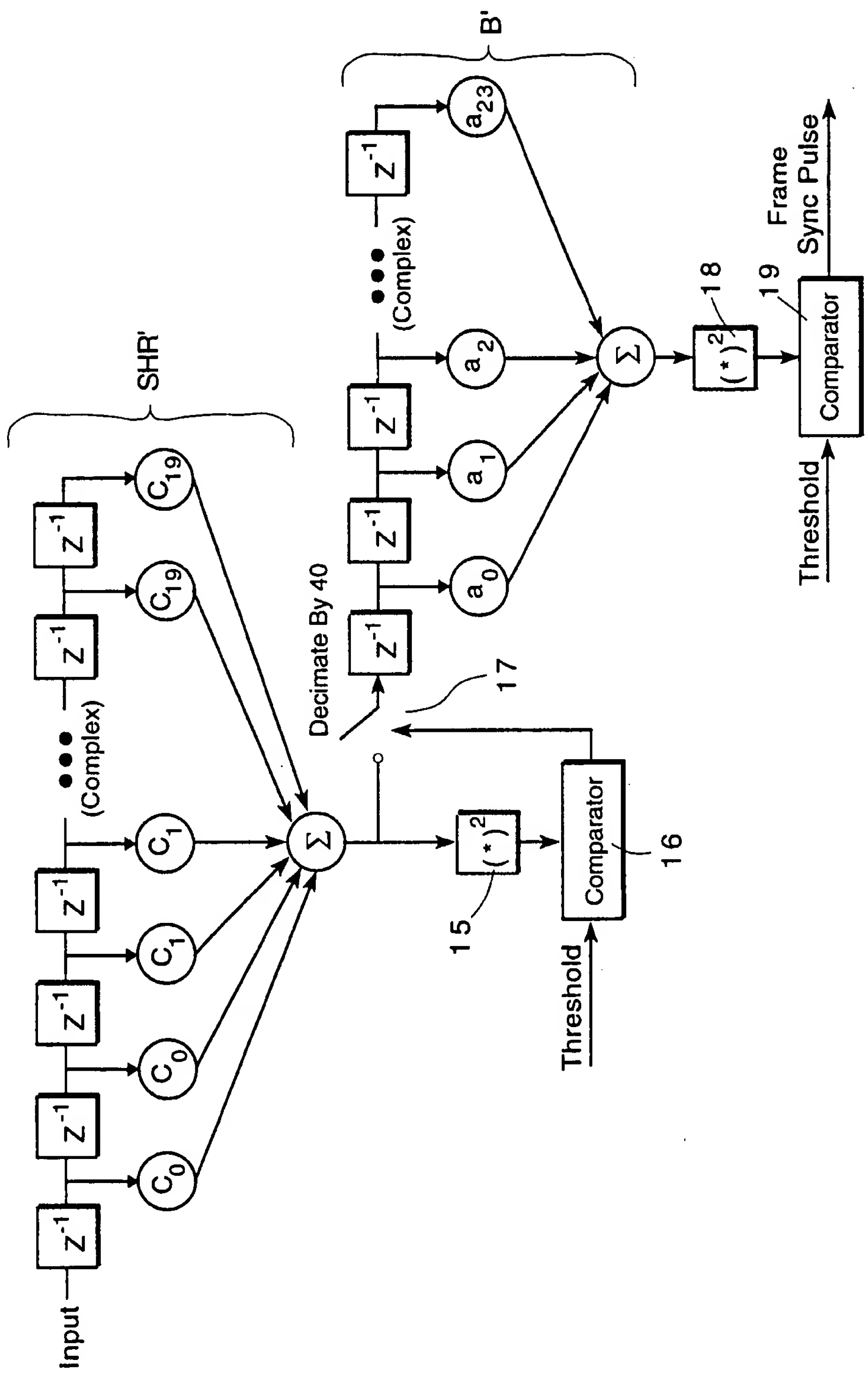
$(*)^2$
z^{-40}
1
(Real)
MAF
COMP
Comparator
Threshold
Frame Sync Pulse

FIG. 6



Input
z^{-1}
C_0
C_1
C_{19}
(Complex)
SHR'
Σ
$(*)^2$
15
Comparator
16
Threshold
17
Decimate By 40
a_0
a_1
a_2
a_{23}
B'
18
19
Frame Sync Pulse

FIG. 7

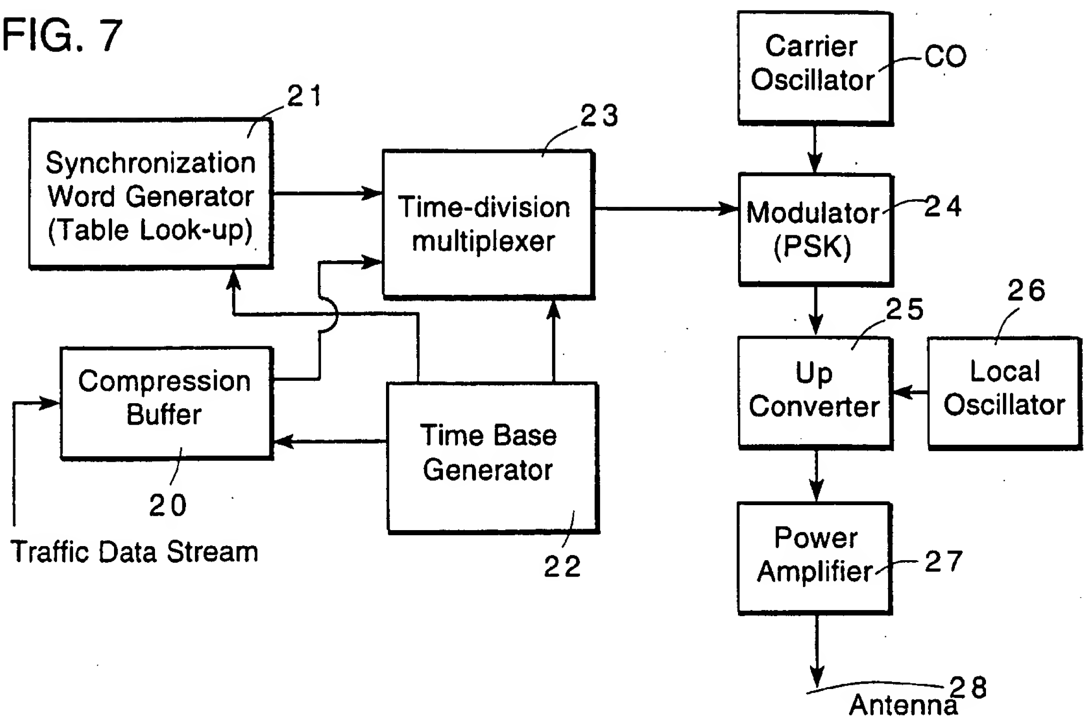
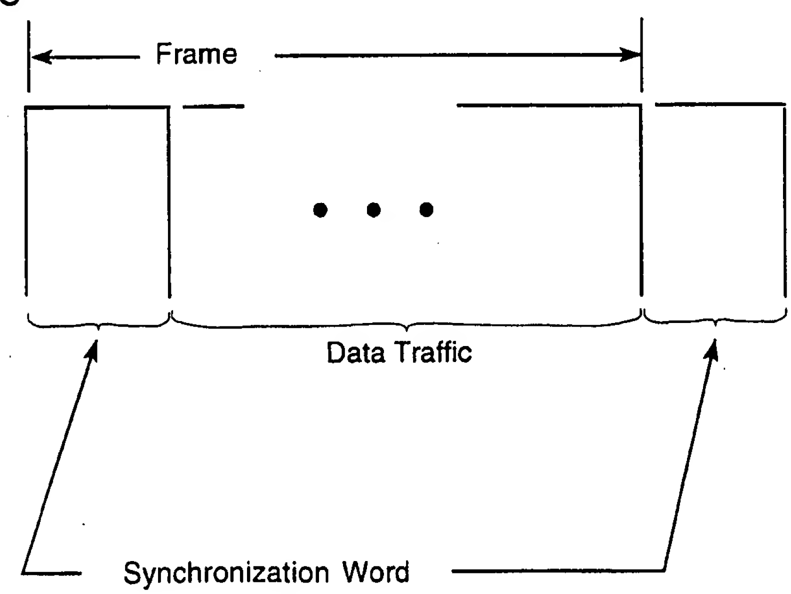

Carrier Oscillator
CO
21
Synchronization Word Generator (Table Look-up)
23
Time-division multiplexer
Modulator (PSK)
24
25
26
Up Converter
Local Oscillator
Compression Buffer
Time Base Generator
20
Traffic Data Stream
22
Power Amplifier
27
28
Antenna

FIG. 8


Frame
Data Traffic
Synchronization Word

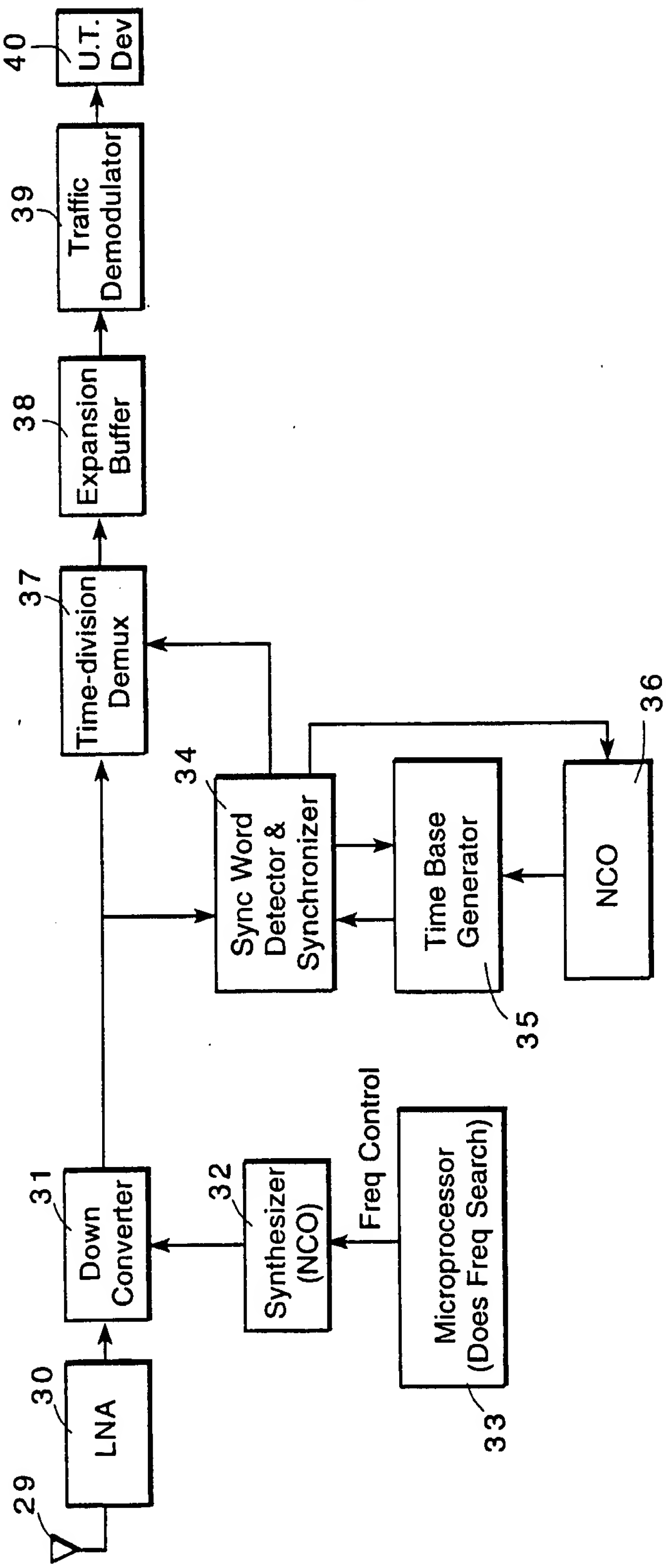

29
30
LNA
31
Down Converter
32
Synthesizer (NCO)
Freq Control
Microprocessor (Does Freq Search)
33
34
Sync Word Detector & Synchronizer
Time Base Generator
35
NCO
36
37
Time-division Demux
38
Expansion Buffer
39
Traffic Demodulator
40
U.T. Dev

FIG. 9

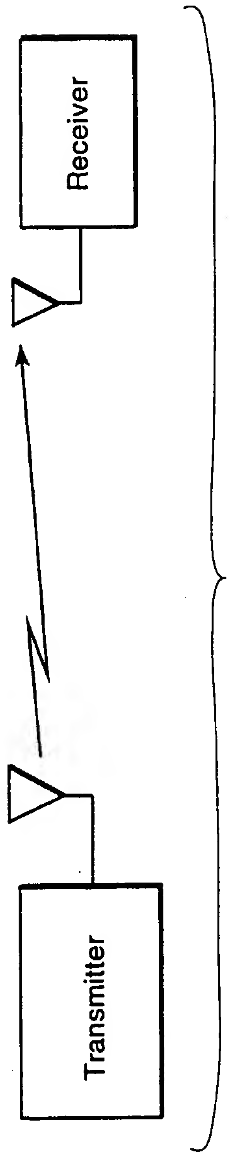


FIG. 10a

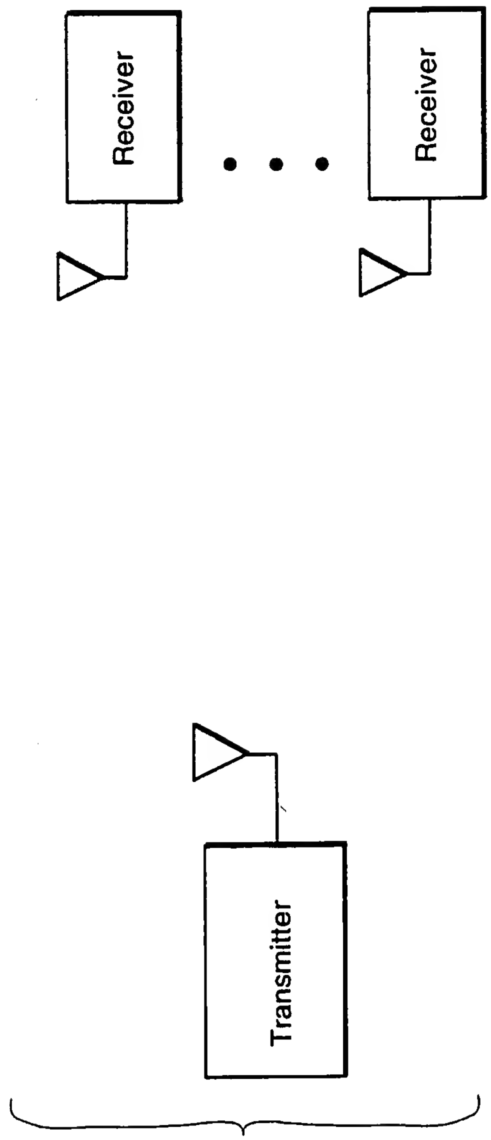


FIG. 10b

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/19159

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : H03D 11/00; H04L 27/06, 7/00
US CL : 375/343, 365
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 375/343, 365, 343, 354, 254, 200, 353, 254, 232; 382/281;

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Please See Extra Sheet.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4,291,409 A (WEINBERG et al) 22 September 1981 (22-09-81), column 5, lines 13-24 and 5-68, column 6, lines 14-18.	1 and 11
Y	US 5,359,627 A (RESNIKOFF) 25 October 1994 (25-10-94), column 17, lines 33-65.	2 and 12
A	US 3,167,738 A (WESTERFIELD) 26 January 1965 (26-01-65), column 2, lines 59-71.	3, 4, 13, and 14
A,E	US 5,696,762 A (NATALI et al) 09 December 1997 (09-12-97), column.3, lines 58-67	7, 8, 9, 17, 18, and 19

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 JANUARY 1998	19 FEB 1998

Name and mailing address of the ISA/US	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/19159

B. FIELDS SEARCHED
Electronic data bases consulted (Name of data base and where practicable terms used):

APS, Bibliographic, Full Text, Software and Product Files, European Patent, Foreign Patent
search terms:synchronization word, matched filter, Kronecker Product, dual or sequential,